THE CORRELATIONS BETWEEN RATE OF TOOL EROSION AND BLACK LAYER FORMATION DURING ELECTRO-DISCHARGE MACHINING

Abstract:

The present assessment is performed in order to develop correlation between the rate of tool eroded and the black film formed while machining on electro discharge machine. The study was performed to detect the major constituents of the black layer and its influence on tool erosion. The major constituents detected were carbon, silicon, iron and oxygen as identified by EDX analysis. It was found that the elevated duty factor results in the higher occurrence of the black layer. The duty factor was the most dominating parameter for the development of the black layer. It depicts that the higher value of τ will lead to more resistance to the positive ions impinging the tool surface, thus contributing minimum TWR.

Keywords: Black Layer, EDM, SEM, EDX

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I. TOOL WEAR RATE AND BLACK LAYER

Electro-Discharge Machining is a technique where the electrode machines the required contour over the work using spark erosion facilitated by dielectric medium. The spark heat removes the material while the dielectric flushes off the detritus from the spark gap. During sparking, a black layer sticks to the tool surface that may impact the efficacy of machining. The blackness over the tool is due to the relocation of carbon through the dielectric [2,5,8]. It results due to correspondence of machine variables with its outcome and it modifies the tool's thermal conduction [1]. This phenomenon occurs at high temperature and it resists tool wear [3].

Other than carbon, the black layer also contains Fe, Cr, V and Molybdenum [2,5]. Its major component is carbon which releases through the dielectric [4]. The thickness of this layer is between 15 to 20 micro-meter that attaches quickly over the tool surface [4]. Temperature distribution also has influence on the formation of the carbon layer over tool surface [4].

The black layer formed during machining is a brittle and exerts influence over tool's thermal conduction [5]. The discharge energy dominates the thickness of the black layer [6]. A higher duty factor also leads to the formation of black layer while it disappears at a lower level of duty factor [7]. This hinders the machining of work material [9]. The dielectric pyrolysis lays a fine black carbon skin over the tool's surface [10].

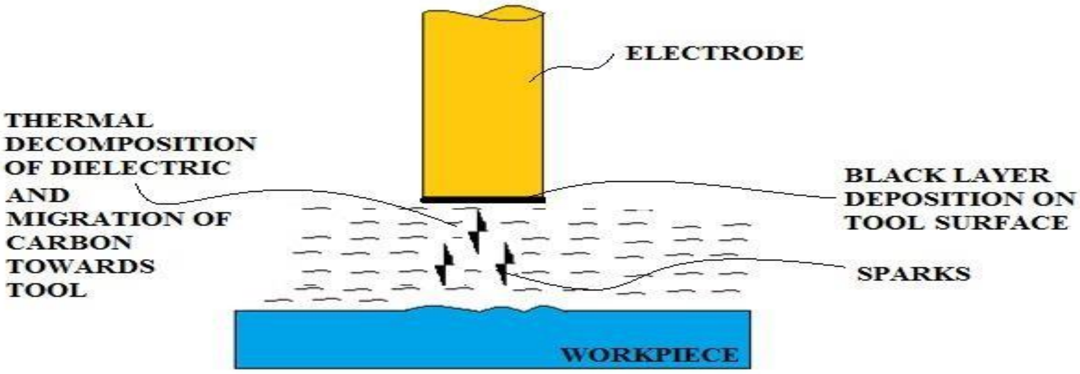


Figure 1: Black Layer over the Tool's surface

Table 1: ANOVA analysis of the 2FI model of Tool Wear Rate

Experiment Specifications	
Work Material	AISI 4340
Tool Material	Copper-Tungsten
Dielectric	Kerosene
Selected Process Parameters	Current, On Duration, Voltage, Duty Factor;

The above table 1 shows the experimental specifications considered for assessing the results.

1.1 Black Layer Formation

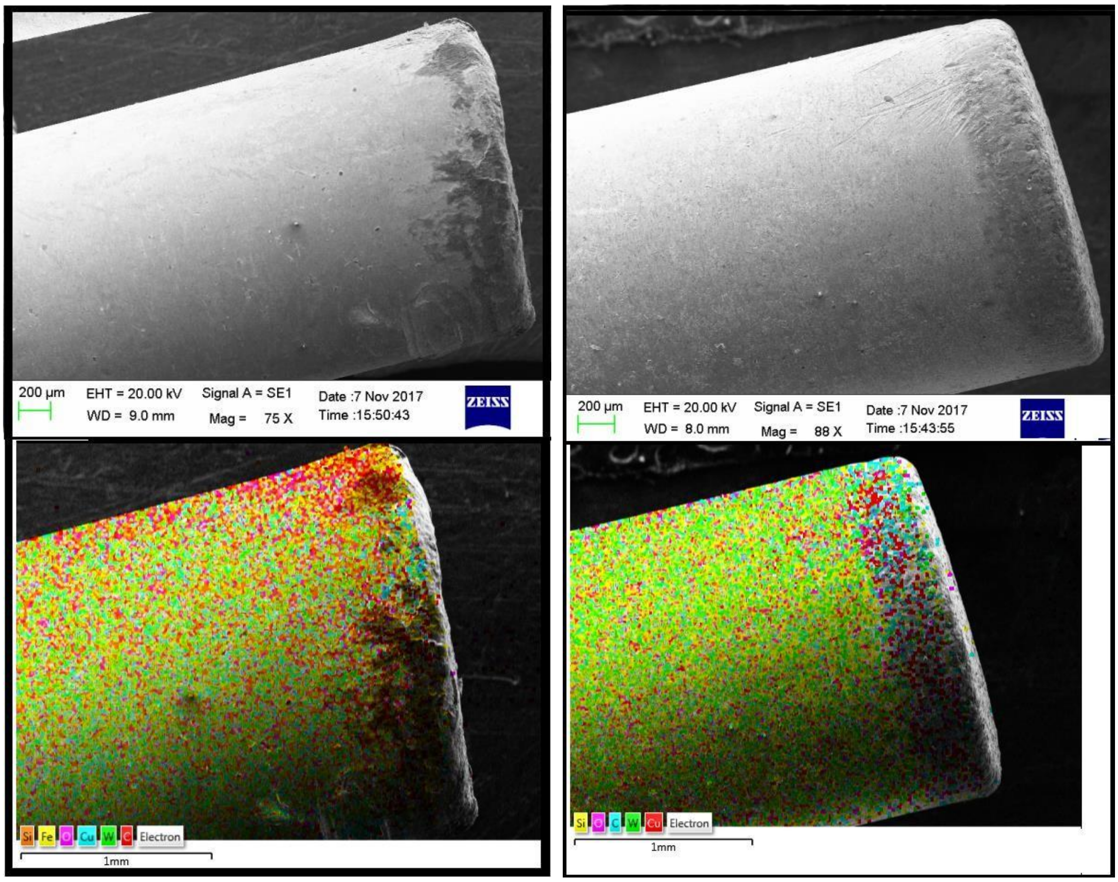
When the electrons travel from the tool because of developed suitable voltage between the tool and work, the spark initiates due to ionization and de-ionization of dielectric medium. Owing to the thermal decay of dielectric medium at elevated temperature developed due to high discharge energy, a thin black film deposition is observed on the tool surface.

Subsequently due to the thermal decomposition, the carbon progresses in the direction of the tool and cover its surface in the form of a layer. This layer resists the positive ions striking the surface of the tool resulting in the lower rate of tool erosion.

Table 2: ANOVA analysis of the 2FI model of Tool Wear Rate

Source	Sum of Square	DOF	Mean Square	F-value	p-value	
Model	0.0329	10	0.0033	7	0.0001	**Significant**
A-Peak Current	0.0092	1	0.0092	19.58	0.0003	
B-Pulse on Time	0.0016	1	0.0016	3.43	0.0789	
C-Voltage	0.0001	1	0.0001	0.2799	0.6026	
D-Pulse duty Factor	0.0146	1	0.0146	31.01	<0.0001	
AB	0.001	1	0.001	2.21	0.1527	
AC	0	1	0	0.0222	0.883	
AD	0.0061	1	0.0061	13	0.0018	
BC	0.0002	1	0.0002	0.4456	0.5121	
BD	2.33E-06	1	2.33E-06	0.005	0.9446	
CD	0	1	0	0.0377	0.8479	
Residual	0.0094	20	0.0005			
Lack of fit	0.0067	14	0.0005	1.07	0.4971	Not significant
Pure Error	0.0027	6	0.0004			
Cor Total	0.0422	30				

The duty factor exerts much influence on tool erosion. It is also detected as a crucial factor as per ANOVA in table 2. It can be observed from scanning electron microscopy images in figure 2 (a), 2 (b) and 3 that the elevated duty factor results in the higher occurrence of the black layer. The TWR of 0.05124 mm^3/min at Ip = 4A, Ton = 25μsec, V = 90V and $\tau = 0.8$ is minimum. It depicts that the higher value of τ will lead to more resistance to the positive ions impinging the tool surface, thus contributing minimum TWR.



(a) **(b)**

Figure 2: Electron Microscopic and Spectroscopic images

(a) Sample 1 (Ip-4A, Ton-15µsec, V-90V, τ-0.6)
(b) Sample 11(Ip-4A, Ton-25µsec, V-90V, τ-0.8)

From the EDX images, the black layer majorly constitutes carbon, silicon, oxygen and iron. The thermal decomposition of dielectric results in carbon deposition, while the other elements account their deposition through the workpiece. The presence of oxygen in the black layer is due to the oxidation during machining process.

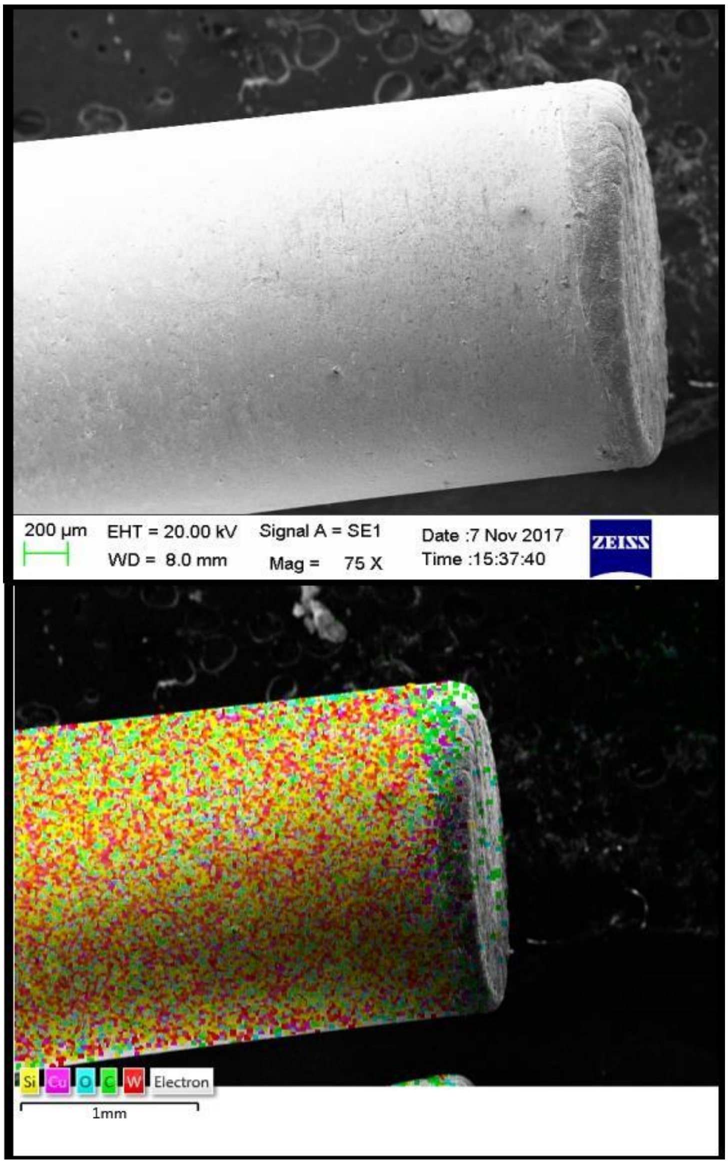


Figure 3: Electron Microscopic and Spectroscopic image of Sample 20 (Ip-7A, Ton-30µsec, V-105V, τ-0.7)

1.2 Effects of black layer over tool erosion

From the previous section we could say that the composition detected in the black layer constitutes other elements along with carbon. These elements are Silicon (Si), Iron (Fe) and Oxygen as identified by EDX analysis. The presence of iron (Fe) and silicon (Si) is due to their migration from the work surface.

The presence of oxygen indicates the oxidation that is caused while machining the work. The elevated duty factor results in the higher occurrence of the black layer. The duty factor was the most dominating parameter for the development of the black layer. It depicts that the higher value of τ will lead to more resistance to the positive ions impinging the tool surface, thus contributing minimum TWR.

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